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Statistical analysis of ejection property of plasma blobs from plasma column in the linear plasma device

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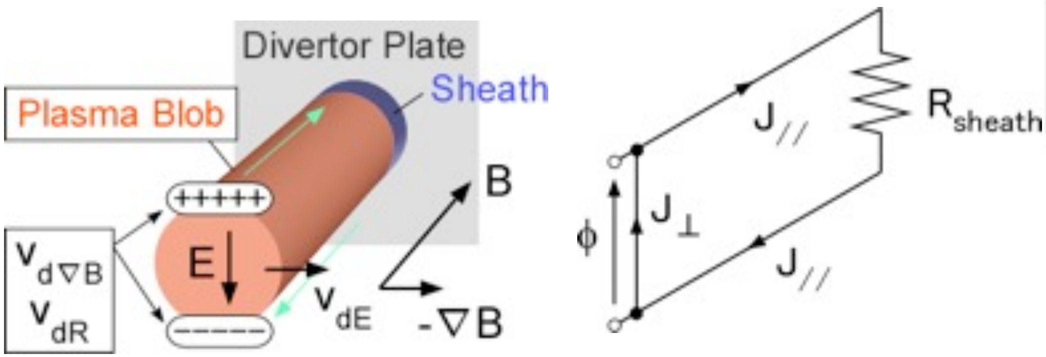
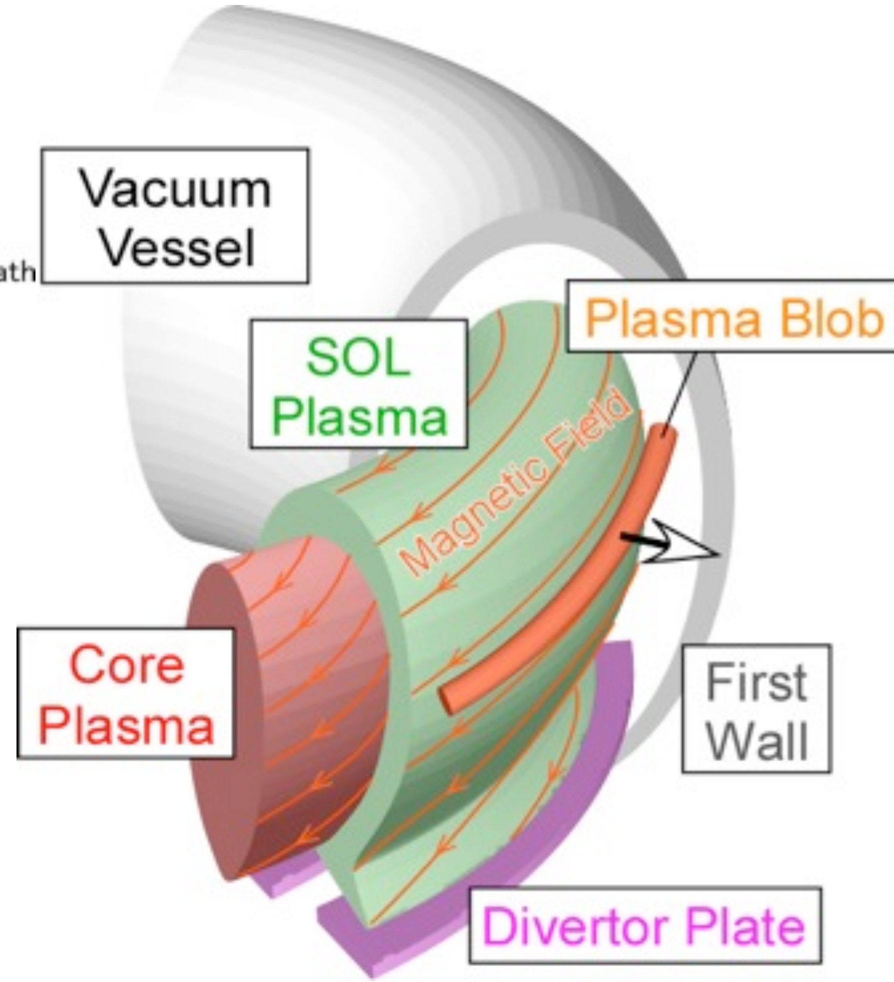
Plasma Blob Study in SOL/Divertor Plasma

Topics:

1) Transport of plasma blobs in SOL/divertor plasma



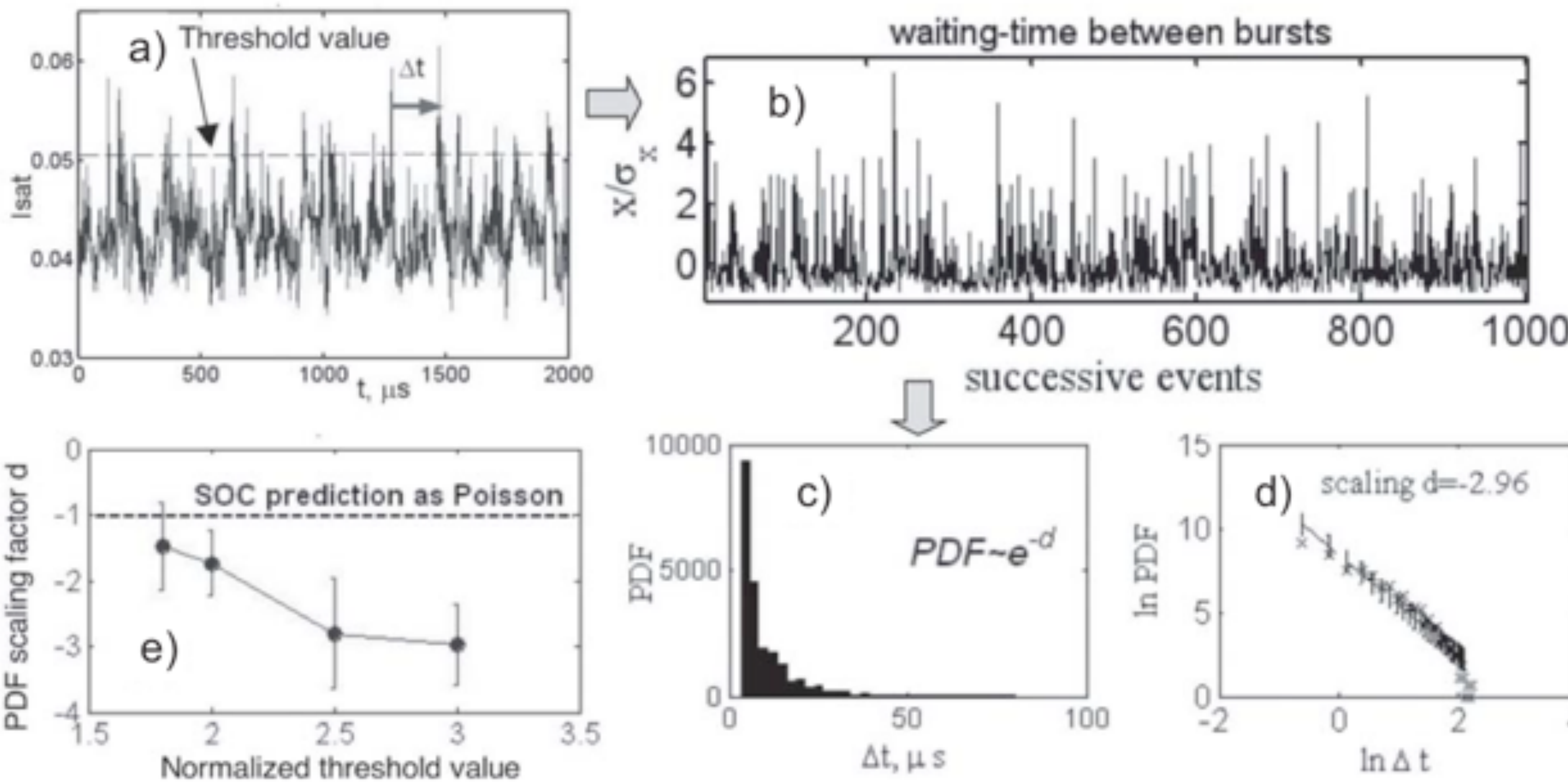
S.I. Krasheninnikov, Phys. Lett. A **283** (2001) 368.



2) Generation statistics and mechanism of plasma blobs

Statistics of plasma blob generation

Waiting-time statistics for bursty signals observed by a divertor probe in LHD



<u>Only in time domain</u> N. Ohno et al. PET9

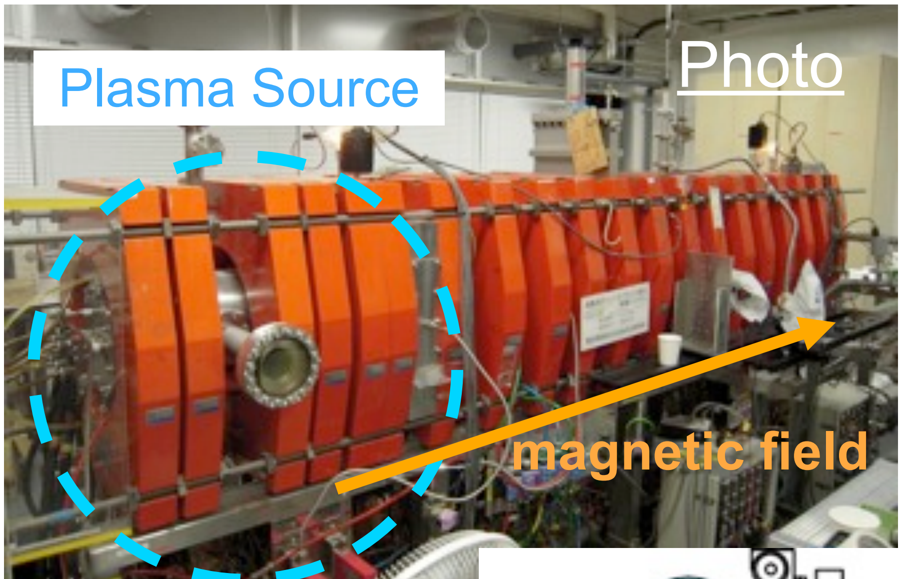
Contrib. Plasma Phys. **46**, No. 7-9 (2006)

In this study,

Statistics of <u>appearance positions</u> of plasma blobs has been analyzed based on 2D images taken in the linear device.

Linear plasma device: NAGDIS-II

NAGDIS-II (**NAG**oya **DI**vertor plasma **S**imulator **- II**)



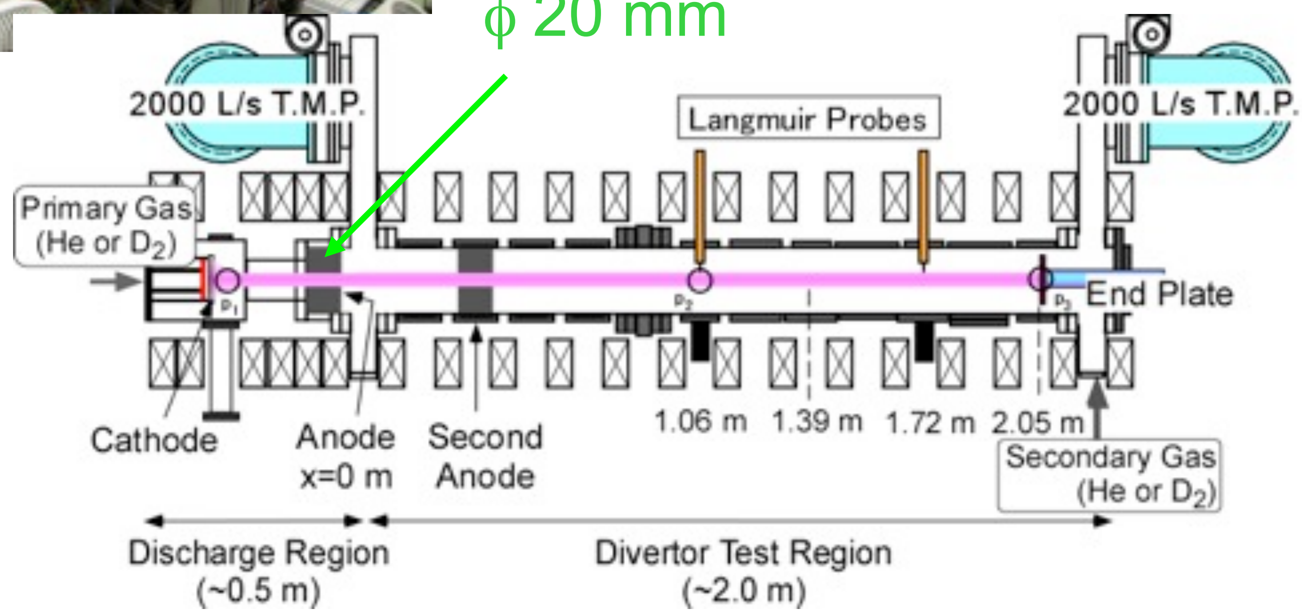
cusp magnetic field

Typical Parameter

$n_e < 10^{20} m^{-3}$, $T_e < 10 eV$

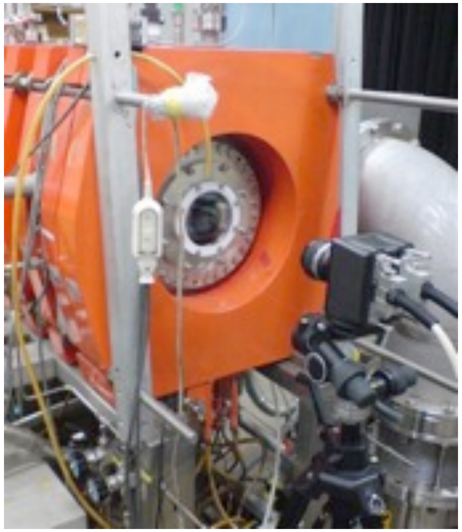
Intermediate electrode
ϕ 20 mm

upper view

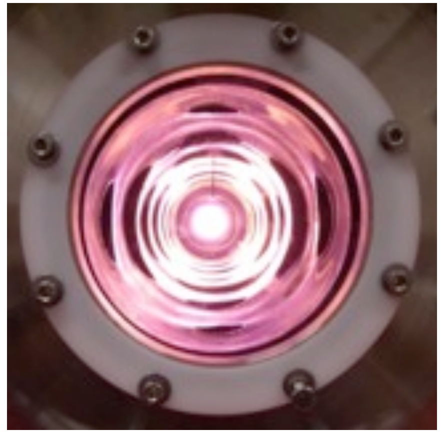


N. Ohno, *et al*., Nucl. Fusion **41** (2001) 1055.

2D structure captured by a fast camera



Photos

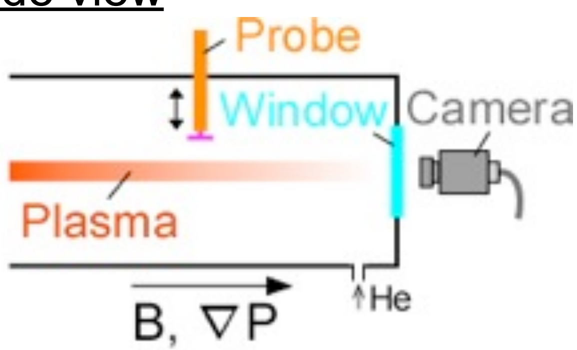


By increasing the neutral gas pressure, plasma in front of viewing port was disappeared

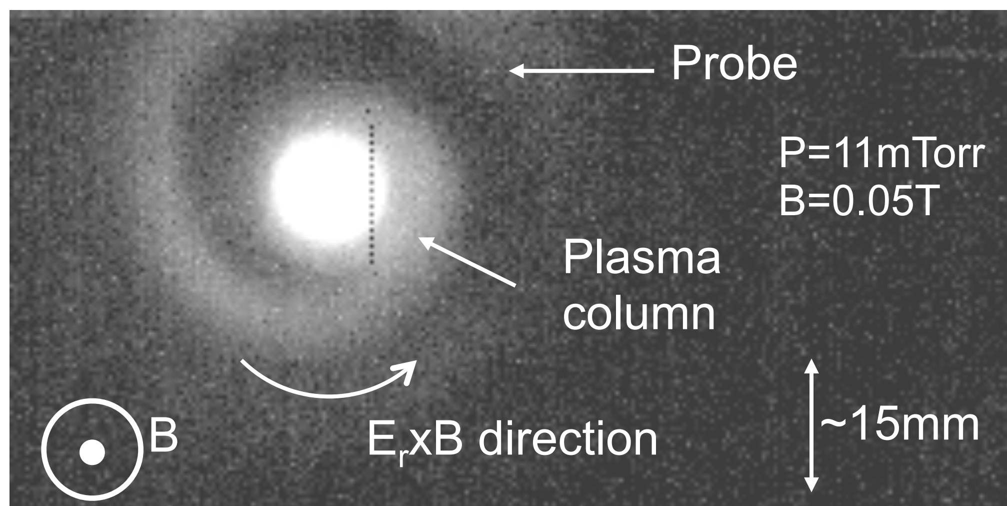
– plasma detachment and

- enhancement of blobby plasma transport

Side view



128x256pixel (~54x108mm^2)

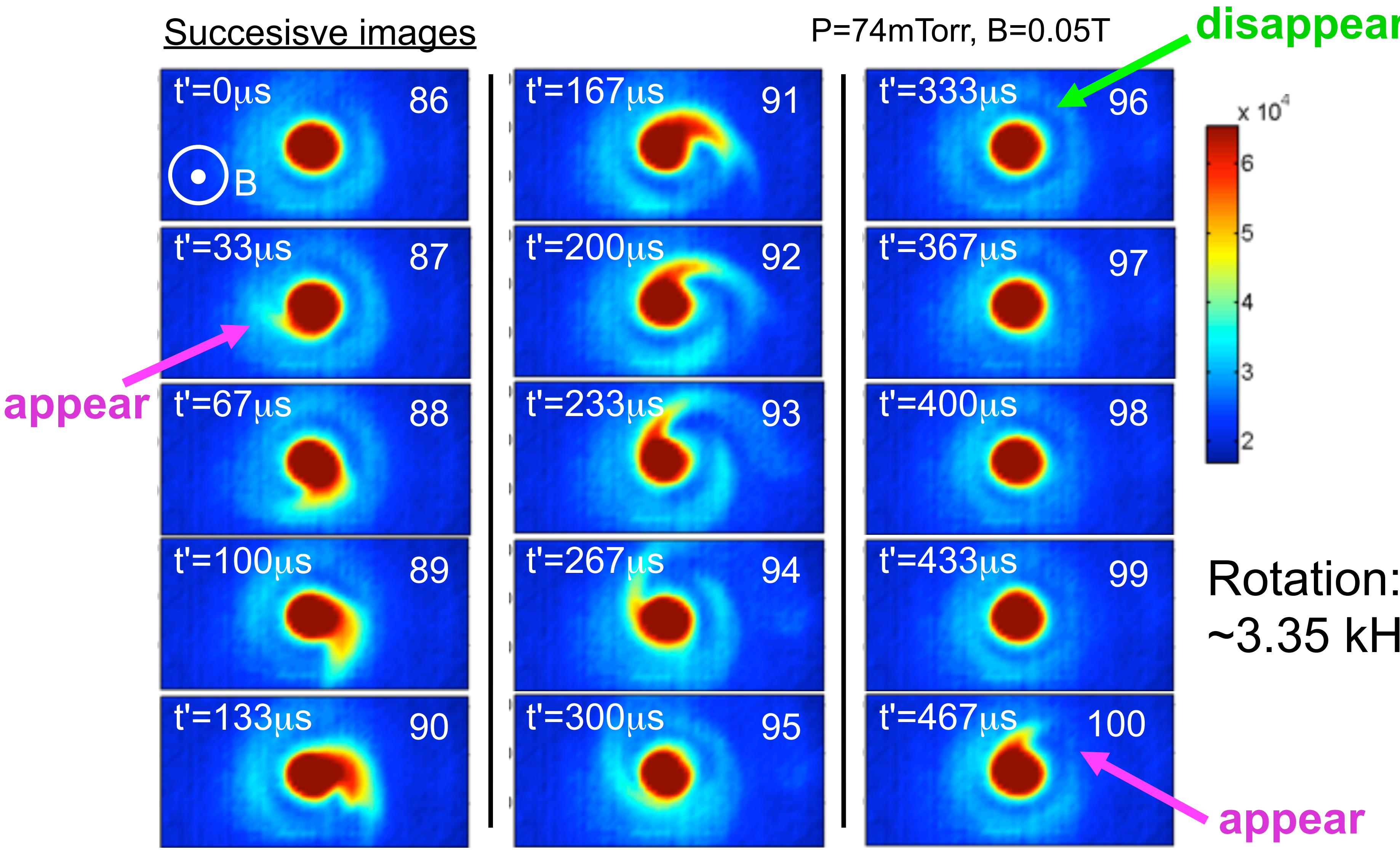


Spiral structures propagate radially and azimuthally.

Snapshots

Succesisve images

P=74mTorr, B=0.05T

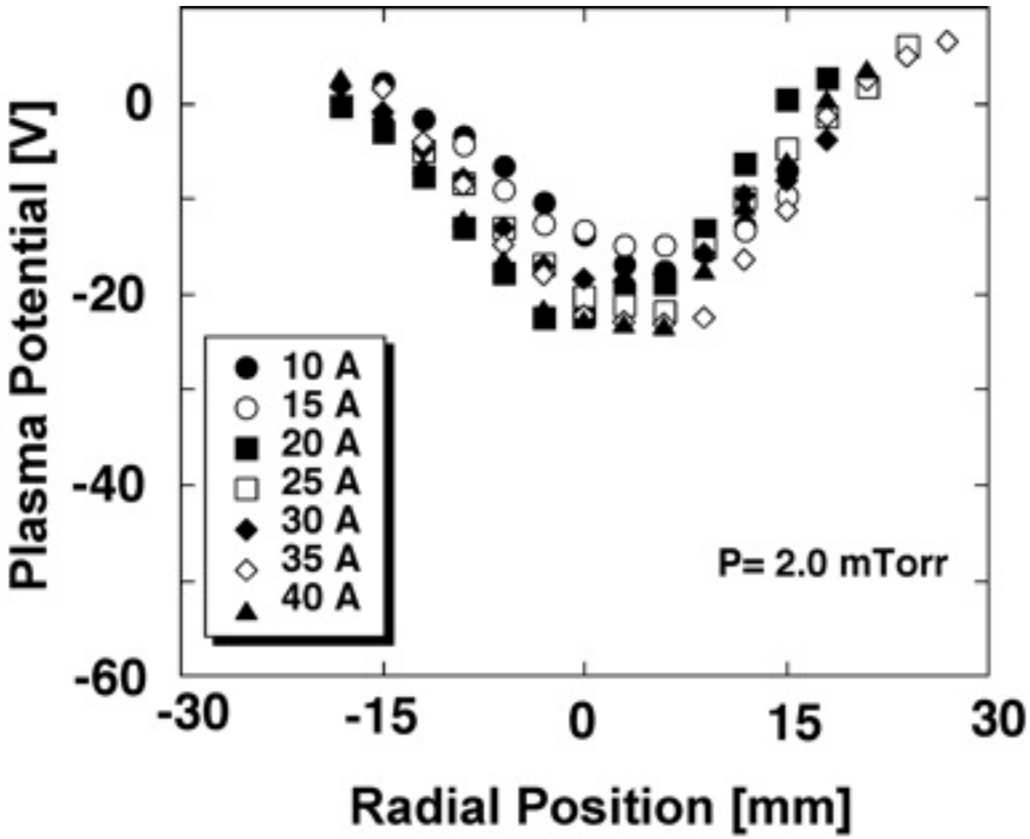


Rotation:
~3.35 kHz

Shutter speed: 100000s^{-1} / Frame rate: 30000fps

Global rotation is determined by ExB drift

Radial plasma potential profile in NAGDIS-II



Radial electric field E_r

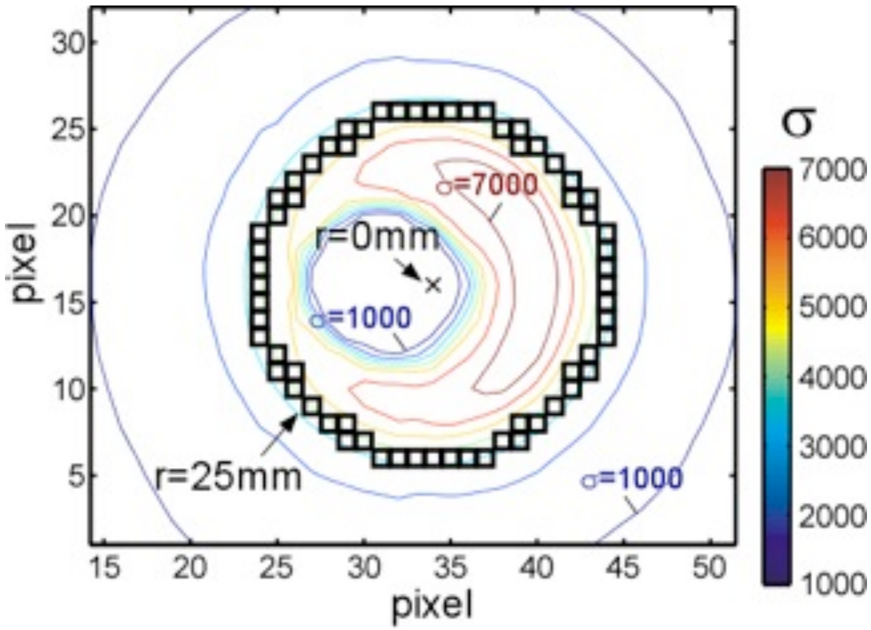
→E_rxB **rotation**

→Centrifugal force

Driving force of blobby plasma transport

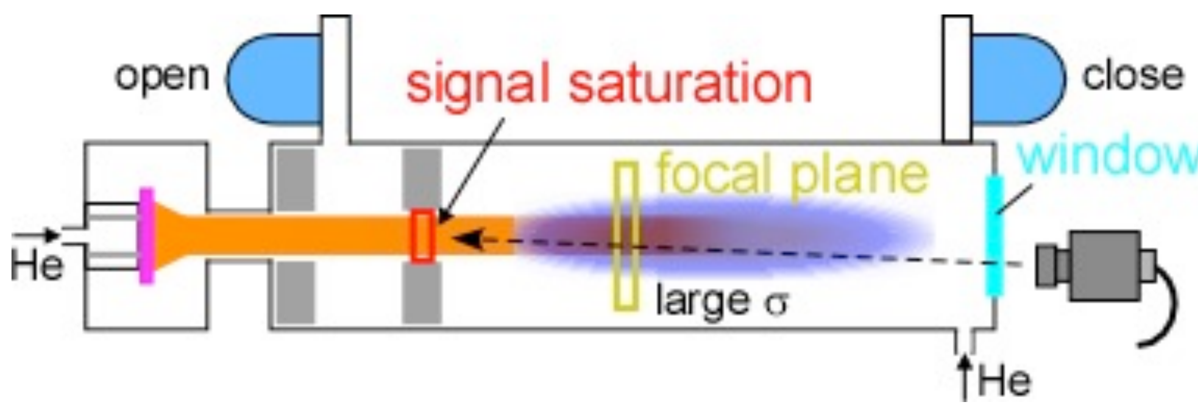
Data extraction in the azimuthal direction

Profile of standard deviation σ



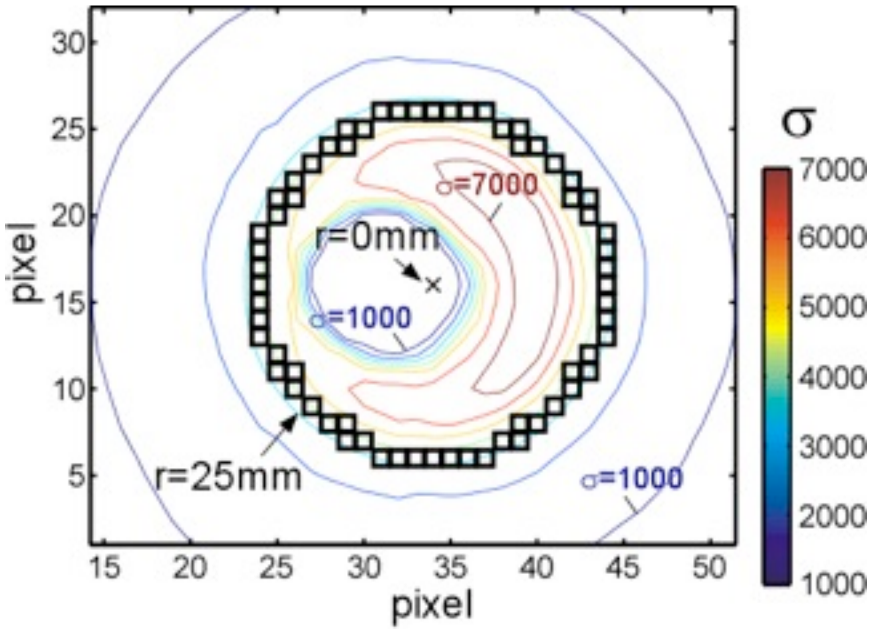
σ profile at r < 25 mm is non-axisymmetric because of signal saturation and out of alignment

Upper view



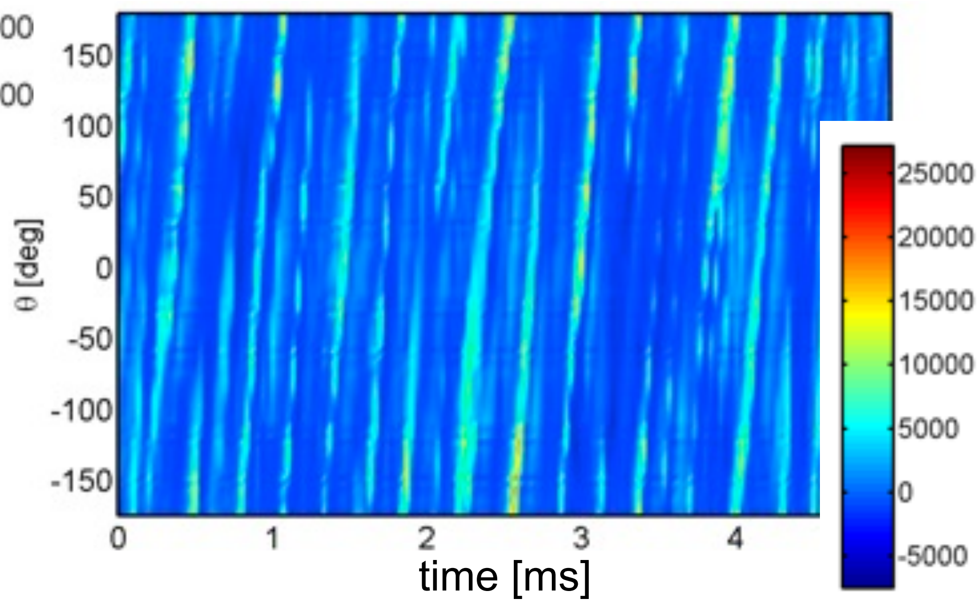
Data extraction in the azimuthal direction

Profile of standard deviation σ



Fluctuation component ($I^f = I - \langle I \rangle$) on each pixel at r ~ 25 mm was plotted as functions of time and azimuthal angle θ

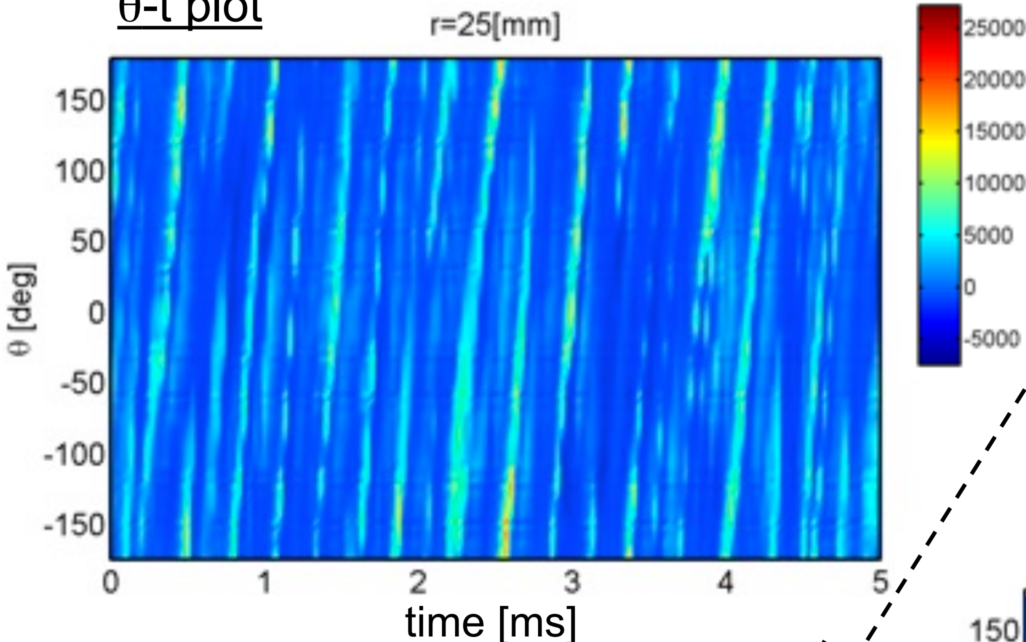
θ-t plot of fluctuation component I^f

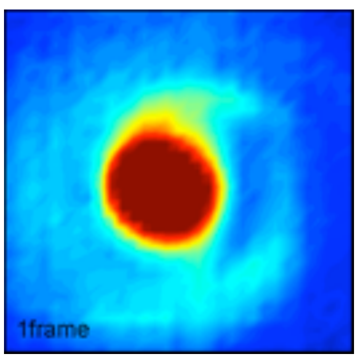


Diagonal lines appear with a constant angle (~3.35 kHz)

Azimuthal position in rotating coordinate system

θ-t plot



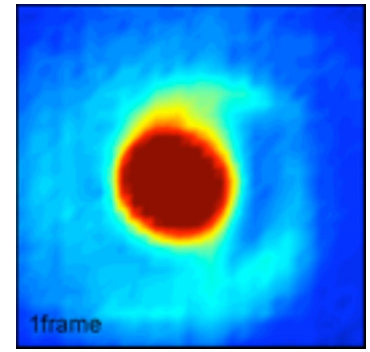


In usual coordinate system

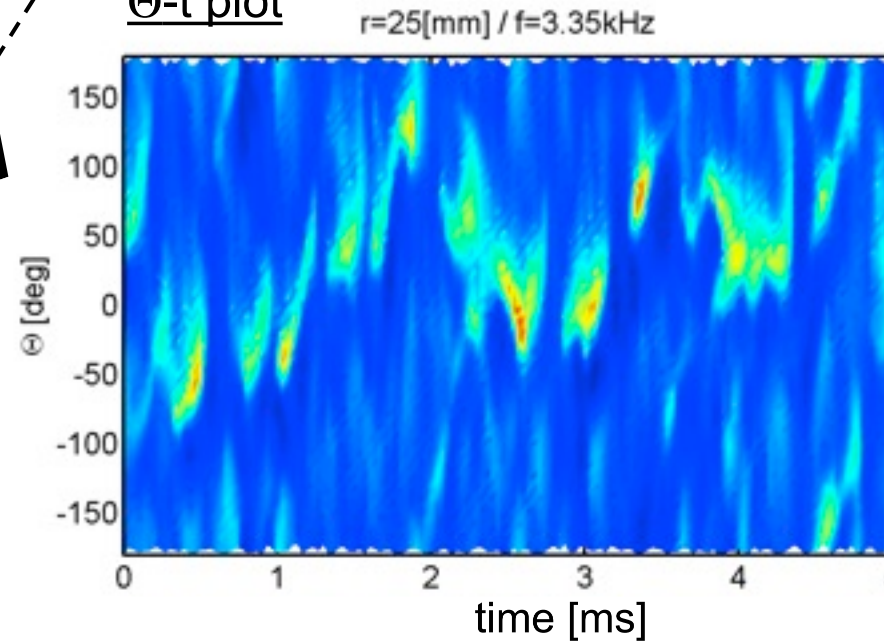
$$\Theta(t) = \theta - 2\pi f t$$

f=3.35kHz

In rotating coordinate system

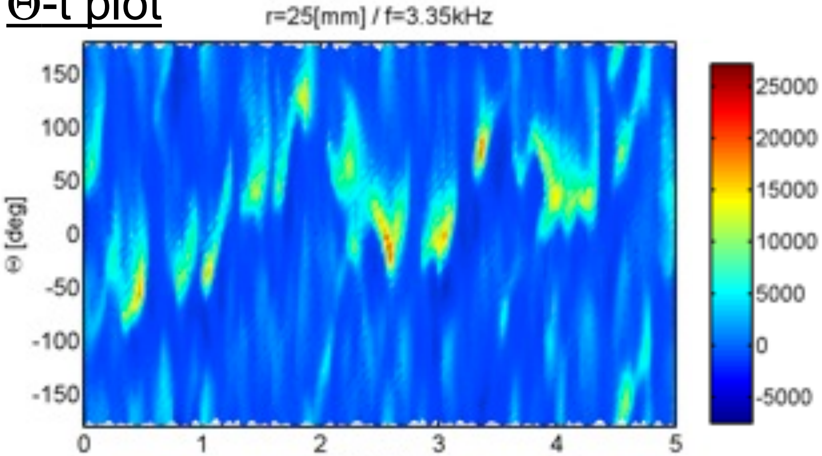


Θ-t plot



Detection of appearance positions

Θ-t plot



time [ms]

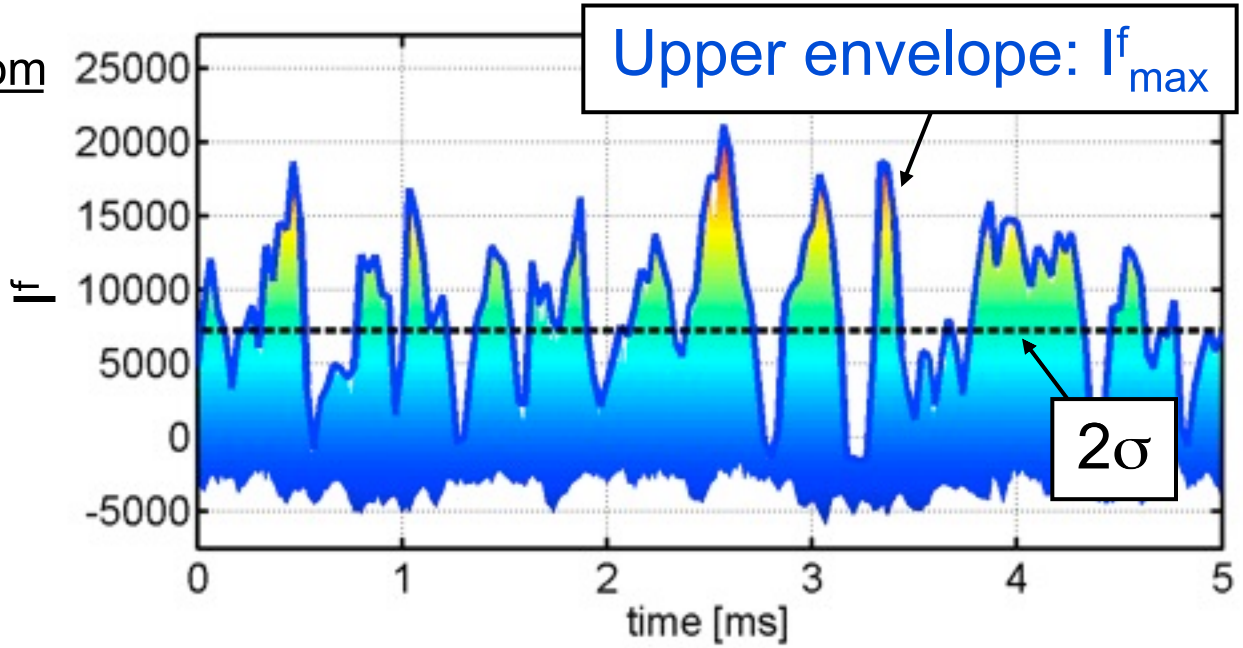
Mean of I^f: μ=0

Standard deviation: σ=3633

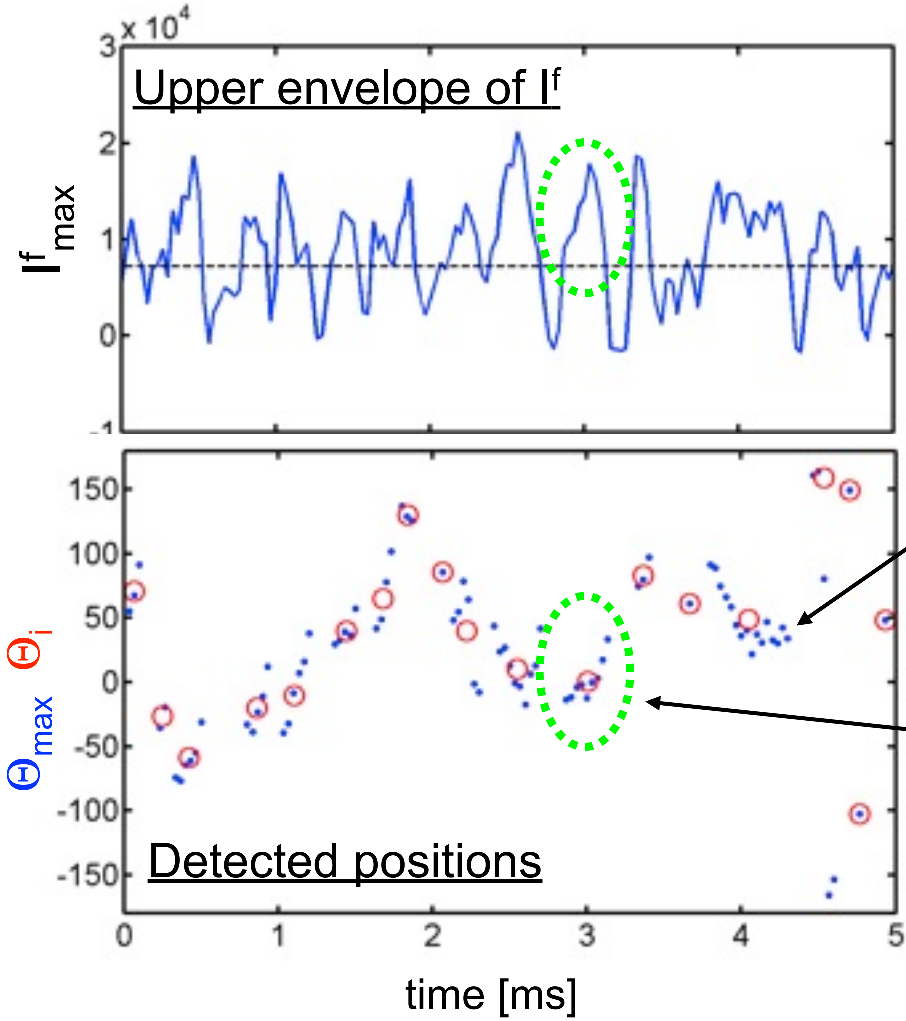
Detection was carried out by setting a threshold level

Θ-t plot from side

Side view



Detection of appearance positions



Blue dots indicate azimuthal angle Θ at $I^f_{max}>2\sigma$, Θ_{max}

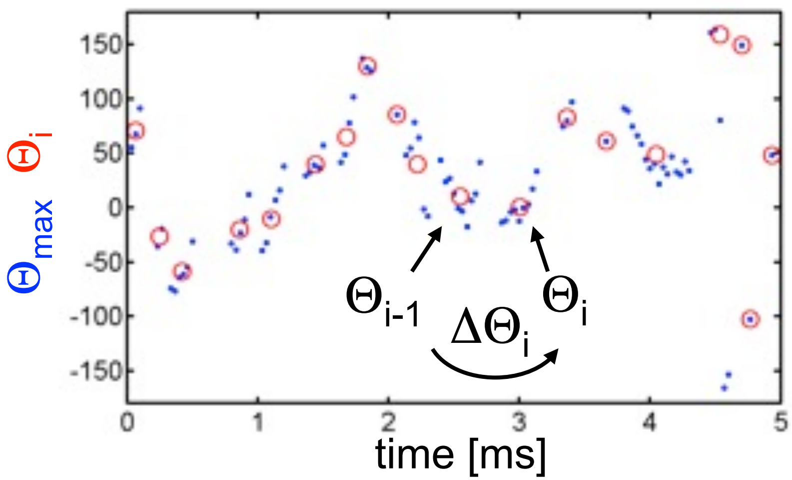
Consecutive Θ_{max} was weighted mean as an appearance, Θ_i, in the range of [-180deg, 180deg)

$$\begin{cases} \Theta_i=(\Sigma_n I^f_{max}{}^{(n)}\Theta_{max}{}^{(n)})/(\Sigma_n I^f_{max}{}^{(n)}) \\ t_i=(\Sigma_n I^f_{max}{}^{(n)}t_{max}{}^{(n)})/(\Sigma_n I^f_{max}{}^{(n)}) \end{cases}$$

Statistics of difference between consecutive steps

Above calculation: -180deg<Θ_i<180deg

Detected positions

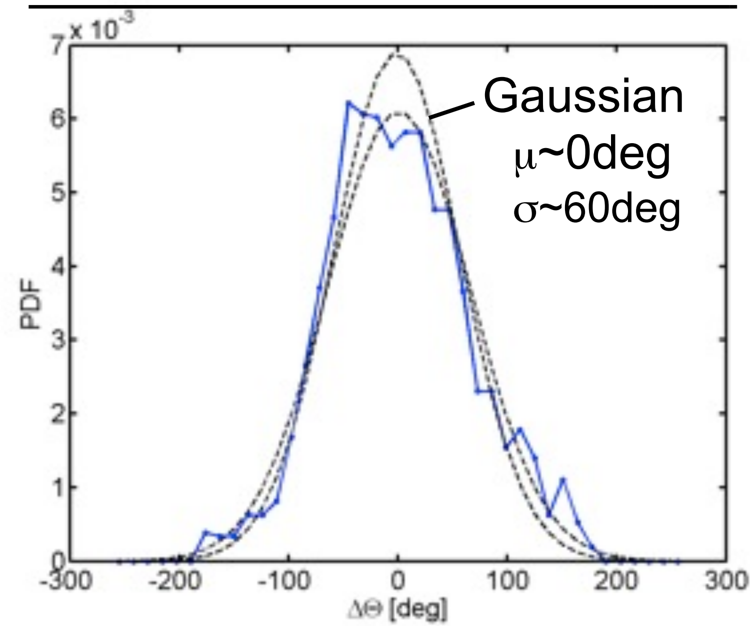


Difference between Θ_{i+1} and Θ_i:

$$\Delta\Theta_i = \Theta_{i+1} - \Theta_i, \left(i \geq 1\right)$$

⇩ **Below, we assume -180deg<$\Delta\Theta_i$<180deg**

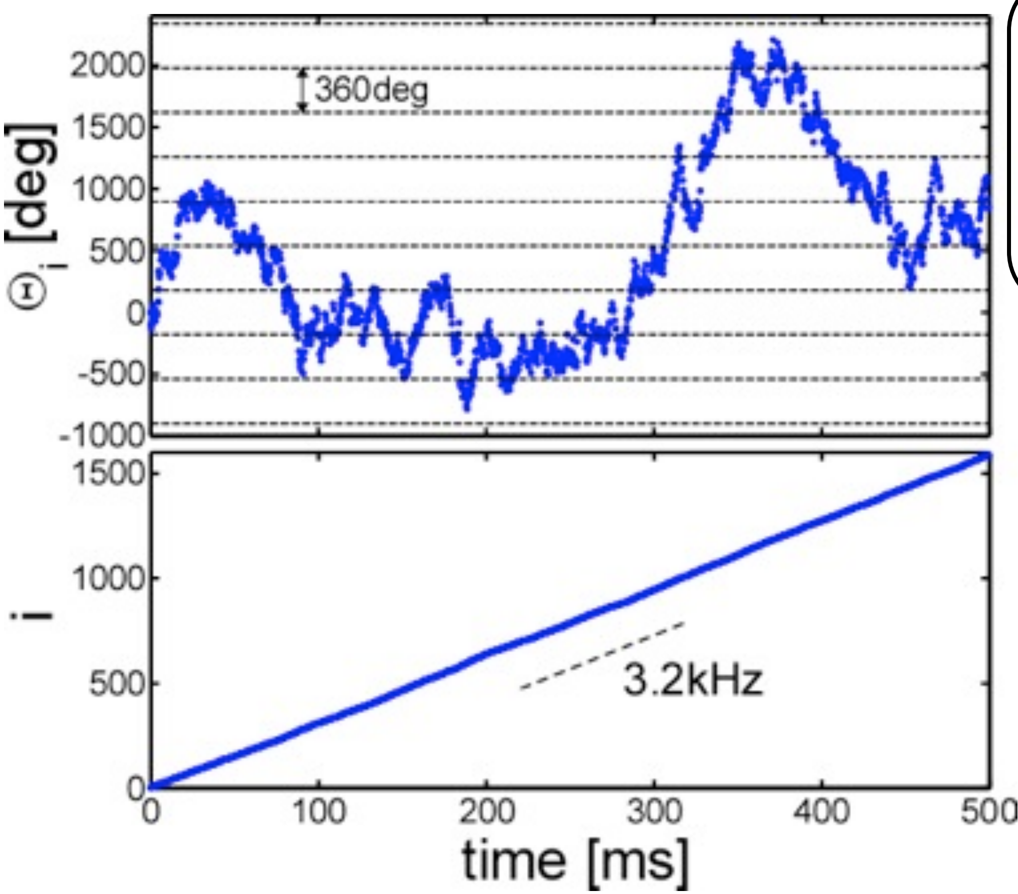
Probability density function of $\Delta\Theta_i$



Zero-mean Gaussian distribution was obtained

Trajectory of the appearance position

Time series of reconstructed Θ_i and i

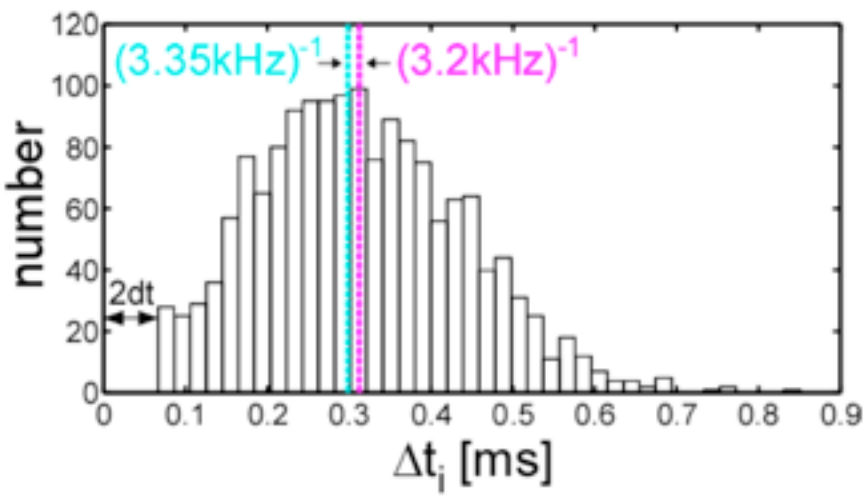


15,000frame

Θ in all range can be reconstructed by accumulation of $\Delta\Theta_i$:

$$\Theta_{i+1} = \sum_{k=1}^{i} \Delta\Theta_k .$$

Θ_i moved in range over 8 revolutions in 500 ms



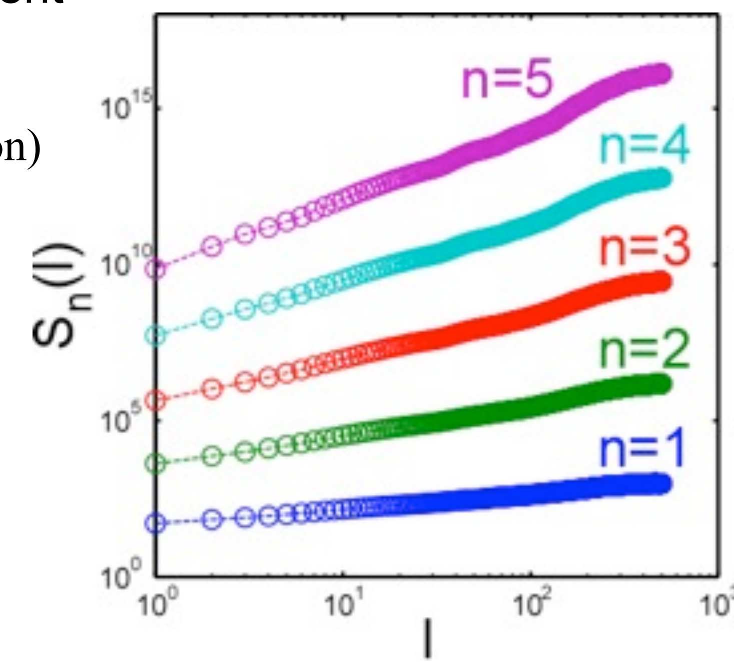
Rescale range analysis

$$S_n(l) = \left\langle \left| \Theta_{i+l} - \Theta_i \right|^n \right\rangle.$$

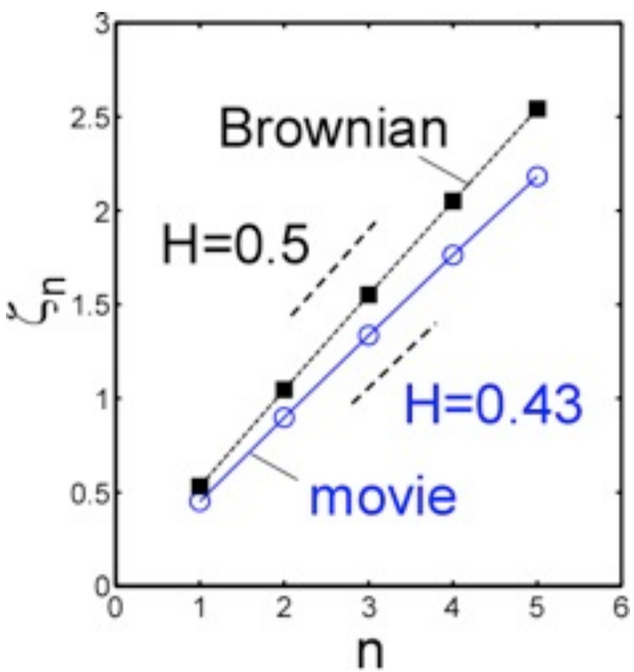
if $\quad S_n(l) \propto l^{\zeta_n}$ and $\zeta_n = Hn \longrightarrow$ H: Hurst exponent

$$\begin{cases} 0 < H < 0.5 & \cdots \text{negative autocorrelation} \\ H = 0.5 & \cdots \text{no correlation (Brownian motion)} \\ 0.5 < H < 1 & \cdots \text{positive autocorrelation} \end{cases}$$

Absolute moments of increments S_n



Exponents of power-law scaling



H of the reconstructed Θ_i is slightly smaller but is close to 0.5 (Brownian motion)

Summary and discussion

- **The trajectory of the reconstructed azimuthal position seems to behave as the Brownian motion around the general rotation**
- **Step size obey zero-mean Gaussian distribution with the standard deviation of ~60 degree**

→ Each coherent structure appeared around the previous appearance position in the rotating coordinate system

- **Each event influence density and potential profiles, and then, next step would be fluctuated**

→ Density and potential fluctuations attributed to the each event would have a key role for determination of spatial statistics